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World trade in forest products and wood fuel

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Abstract

Wood fuel is a strategic resource for future energy supply and is usually utilised locally. Traditional use of wood fuel and other bioenergy has a share of 10–15% energy supply, used mainly for the household sector. The utilisation for industrial purposes is much smaller but is a strategic resource in the effort to fulfil the Kyoto agreement to replace fossil fuels and to mitigate greenhouse gas emissions. Many industrialised countries already use a significant share of biofuels in their energy supply e.g. Nordic countries while others like some other European Union countries are planning to increase their use. Production and use of biofuels need to be carried out sustainable. Official statistics do not report trade in such detail that international trade in different biomass types can be fully identified. However, FAO and European Forestry Institute are important sources. In some countries, there is a growing interest in the international trade, because the trade can provide biofuels at lower prices, larger quantities and better quality than domestic alternatives. The first signs of an international market price for wood fuel are indicated in Europe. For the future both the use and the trade of wood fuel is expected to increase. Analyses for trade in charcoal, wood chips, fuel wood and wood residues made in this report identify 'hot' trade spots in Europe, in south East Asia and in North America.

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1. Introduction

World timber trade has been established for centuries and can be regarded as a traditional part of international trade.

Fossil fuels dominate world energy use but traditional use of biomass[1] as fuel is still significant, some 10–15% of the world energy use [1]. By tradition, local production of wood fuel and local use dominate. Markets have been established within countries or regions mainly for non-industrial use. Other existing users of wood fuel are the forest products industry, especially pulp and paper industries. The forest products industry produces large quantities of wood as by-products which may be used as fuel.

Forest resources are spread all over the globe. Some areas have very large forest resources, e.g. tropical and boreal areas. Countries with large forest resources are Brazil, Indonesia, Russia and Canada. Demand for timber products is connected to dense and fast growing populations. This is the basic driving force for trade in timber. Countries with large forest resources close to a demand and a market have an advantage compared to more remote resources.

The Kyoto Agreement to reduce emissions of greenhouse gases has put pressure on renewable energy sources and world forest resources become an even more strategic resource. Biofuels are one of the renewable sources of energy which are available and the industrial use of wood fuel[2] especially has increased. The main industrial use is for

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[1] *Biomass* is defined as material of biological origin excluded material embedded in geological formations and transformed to fossil. *Biofuel* is defined as fuels produced directly or indirectly from biomass. *Bioenergy* is defined as energy from biofuels [4].

[2] *Wood fuel* is defined as all types of biofuels originating directly or indirectly from woody biomass. *Woody biomass* is defined as biomass from trees, bushes and shrubs [4].

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heat production, electricity production both in stand-alone plants and in combined heat and power plants (CHP-plants). Utilisation of biofuels can be as a single fuel or as co-combustion in existing plants, often together with coal or other fossil fuels [2].

The European Union countries have jointly signed the Kyoto Agreement and have rather ambitious plans for reduction of greenhouse gases. In Europe trade of emissions started in 2005 and there are also systems with green certificates for electricity introduced in countries like Sweden. This development increases the demand for all renewable energy including wood fuel.

Asian countries have a very fast growing economy and are studying the possibilities to increase the use of renewables. The timber trade is well established in this region. Wood-fuel consumption for Asian RWEDP-countries[3] is estimated at 10,000 PJ per year [3]. Increase in wood fuel use by 1.6% per year is reported and the value today is 30 billion USD per annum. Most of this utilisation is available at local markets. Typical prices are 40 USD per tonne.

1.1. Biofuel trade

Processing of wood to charcoal[4] makes transportation more efficient as the energy value increases. The same result is achieved with upgrading of wood raw material to pellets or briquettes.[5]

An early study on European biofuel trade was made in 1993 [5]. More recently, import to Sweden of biofuel has been studied [6,7]. The import was estimated to 15–24 PJ annually, which was around one-third of the demand for the district-heating sector in the country. This is an example of market-based trade were volumes vary due to prices, qualities, availability, etc. Calculations of import to the Netherlands have also been made by Agterberg [8], and Suurs [9].

Wider analyses for Europe have been made [10,11]. In the later study, the European wood fuel price was estimated around 3.5 €GJ.

Large-scale international trade has been analysed [12,13]. Global biomass energy potentials between 100 and 400 EJ was estimated by the first authors and impact on CO_2 emissions with selected bioenergy chains by the latter authors. Global biomass fuel resources were estimated at about 100 EJ/annum by Parikka [14].

World trade was studied in [15] and impacts on policy are given in [16].

1.2. Aim of the study

The purpose of this study is to give a broad picture of the world trade in wood fuel and to map today's trade patterns. Since timber trade and wood fuel trade is assumed to be well connected and reflect forest resources and potentials for wood fuel, statistics for these are also given. Trade is expected to increase and this study will give a better future understanding and give a starting point for this development.

2. Materials and methods

2.1. Introduction

Industrial wood fuel production is closely related to the forestry and forest products industry. Both in terms of the direct harvest of fuel wood and other forest fuels taking place in the forest, but also as a result of the fuel potential implied in the wood residues generated at different stages in the production chain for different wood products. As a result, wood fuel production and trade are naturally analysed in close relation to forest products in general. The most accessible production and trade statistics are not designed to account in detail for all wood fuel products, the growing trade in wood pellets is an example, however, for some fuels good statistics exist, as will be shown below. As a hypothesis, the trade in timber reflects the potential for production and trade in forest products. This will indicate which regions are most active, both in terms of production and trade in forest products. The focus will then be more on wood fuels. The analysis is more detailed, and focuses from global to individual country. A trade matrix is presented, identifying the most active trading partners.

2.2. Statistics

There is no single source for wood-fuel statistics available at the global level. However, there is a possibility to estimate volumes, trade patterns, etc. using the connections to forest products trade. In that sector international statistics are established covering both volumes and trade patterns. Data are held by the Food and Agriculture Organisation (FAO).

The technique used in this paper in order to describe the trade patterns is to use a matrix to cross analyse the data given for exporting and importing countries. In order to describe the trade patterns in the trade flow table the exporting countries are analysed down the columns and the importing countries across in the lines.

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[3] *RWEDP*: The Regional Wood Energy Development Program in Asia, which is a long-term program of FAO including the 16 most important Asian countries.

[4] *Charcoal* refers to a solid residue derived from carbonization, distillation, pyrolysis and torrefaction of wood. It also includes charcoal briquettes.

[5] *Densified wood-fuels* consist of wood fuel compressed to briquette with a diameter less or equal than 25 mm; wood-fuel pellet with a diameter less than 25 mm; wood-fuel powder is upgraded to a main fraction less than 1 mm.

3. Production and trade in timber, forest products and wood fuels

3.1. Production of timber

The world production of round wood for the period 2000–2002 has been approximately 3400 million cubic metres annually. Around 30% is produced in Asia (Table 1). The second largest round wood-producing region is North and Central America (around 23%), followed by Africa (18%) and Europe (17%).

The round wood volumes are an indicator of the total volume of forestry production. One of the subcategories of wood products is pulpwood (Table 2). Here Europe and North and Central America are clearly the largest producers, each accounting for 35–40% annual production of around 480 million cubic metres. South America is the third largest pulpwood-producing region, with 13%.

World production of sawn wood displays a similar pattern. Around 380 million cubic metres are produced annually (2000–2002), and again Europe (33%) and North and Central America (38%) account for similar shares (Table 3). Asia also contributes a substantial share in this production, with around 16%.

3.2. Production of wood-based fuels

As shown in Table 4, most of the on average 41 million tonnes of charcoal produced annually comes from Africa (51%) and in South America (35%).

Finally, on the aggregate level, statistics on production of wood fuel indicate an annual world production in the neighbourhood of 1800 million cubic metres during the 2000–2002 period. Asia, at approximately 44%, and Africa, 30%, again are the major producing regions (Table 5).

3.3. Trade in forest products

To get an idea of the major trade flows of forest products, exports and imports between the world's regions are presented (Table 6). The total value of trade in forest products during 2000–2002 varies from 131 to 145 billion USD, and half of this value is accounted for by the exports from the European counties. North and Central America is

Table 1
World round wood production by region, absolute (million cubic metres) and relative numbers [17]

Region	2000		2001		2002	
	Mill m^3	Share (%)	Mill m^3	Share (%)	Mill m^3	Share (%)
Africa	595.4	17.5	602.6	18.0	617.1	18.3
Asia	1020.0	30.0	1011.5	30.2	999.5	29.6
Europe and	591.8	17.4	564.8	16.9	588.1	17.4
North and Central America	794.2	23.4	764.7	22.9	773.5	22.9
Oceania	59.9	1.8	61.5	1.8	61.9	1.8
South America	339.0	10.0	340.1	10.2	340.3	10.1
World	3400.3	100.0	3345.2	100.0	3380.5	100.0

Table 2
World production of pulpwood (round and split) by region, absolute (million cubic metres) and relative numbers [17]

Region	2000		2001		2002	
	Mill m^3	Share (%)	Mill m^3	Share (%)	Mill m^3	Share (%)
Africa	10.7	2.2	10.7	2.3	10.7	2.2
Asia	22.8	4.7	21.5	4.5	22.0	4.5
Europe	176.5	36.5	172.3	36.2	180.0	37.2
North and Central America	193.9	40.0	190.3	40.0	190.8	39.4
Oceania	16.1	3.3	16.5	3.5	16.5	3.4
South America	64.2	13.3	64.3	13.5	64.3	13.3
World	484.2	100.0	475.6	100.0	484.3	100.0

Table 3
World production of sawn wood by region, absolute (million cubic metres) and relative numbers [17]

Region	2000		2001		2002	
	m^3	Share (%)	m^3	Share (%)	m^3	Share (%)
Africa	8.1	2.1	8.4	2.2	8.4	2.2
Asia	62.2	16.0	60.2	16.0	60.9	15.7
Europe	129.3	33.3	127.8	33.9	130.8	33.6
North and Central America	146.7	37.8	139.1	36.9	147.4	37.9
Oceania	8.2	2.1	7.7	2.0	7.7	2.0
South America	33.6	8.7	33.7	8.9	33.7	8.7
World	388.1	100.0	376.9	100.0	388.9	100.0

Table 4
World production of wood charcoal by region, absolute (in million metric tons) and relative numbers [17]

Region	2000		2001		2002	
	Mill tons	Share (%)	Mill tons	Share (%)	Mill tons	Share (%)
Africa	19.8	50.3	20.9	51.3	21.7	51.2
Asia	4.2	10.6	4.3	10.6	4.4	10.3
Europe	0.3	0.7	0.0	0.1	0.0	0.1
North and Central America	1.2	3.1	1.2	3.0	1.2	2.9
Oceania	0.0	0.0	0.0	0.0	0.0	0.0
South America	13.8	35.1	14.0	34.3	14.8	34.9
World	39.2	100.0	40.8	100.0	42.4	100.0

Table 5
World production of wood fuel by region, absolute (million cubic metres) and relative numbers [17]

Region	2000		2001		2002	
	Mill m^3	Share (%)	Mill m^3	Share (%)	Mill m^3	Share (%)
Africa	527.5	29.5	534.5	29.9	552.4	30.7
Asia	797.7	44.5	795.5	44.5	782.2	43.4
Europe	109.2	6.1	101.4	5.7	105.7	5.9
North and Central America	155.6	8.7	156.3	8.7	158.6	8.8
Oceania	12.2	0.7	12.6	0.7	13.0	0.7
South America	188.5	10.5	189.2	10.6	189.4	10.5
World	1790.7	100.0	1789.5	100.0	1801.3	100.0

Table 6
Exports of forest products by region, billion USD [17]

Region	2000		2001		2002	
	Bill. $	Share (%)	Bill. $	Share (%)	Bill. $	Share (%)
Africa	2.9	2.0	2.8	2.2	2.8	2.1
Asia	17.7	12.2	17.0	12.9	17.0	12.8
Europe	71.2	49.1	65.3	49.6	69.2	51.9
North and Central America	45.1	31.1	39.1	29.7	36.9	27.7
Oceania	2.6	1.8	2.4	1.8	2.4	1.8
South America	5.6	3.8	5.0	3.8	5.0	3.7
World	145.0	100.0	131.6	100.0	133.3	100.0

Table 7
Imports of forest products by region, billion USD [17]

Region	2000		2001		2002	
	Value	Share (%)	Value	Share (%)	Value	Share (%)
Africa	2.6	1.7	2.6	1.8	2.6	1.8
Asia	43.0	28.1	39.4	27.7	39.7	28.0
Europe	68.5	44.7	64.1	45.1	63.8	45.1
North and Central America	34.1	22.2	31.6	22.2	30.9	21.9
Oceania	2.1	1.4	1.6	1.2	1.6	1.2
South America	3.1	2.0	2.9	2.0	2.9	2.0
World	153.4	100.0	142.2	100.0	141.4	100.0

Table 8
Countries with year 2000 forest product exports greater than 1 billion USD [17]

Country	Value, 1000 USD	percent	Cum. percent
Canada	29,715,800	20.45	20.45
United States of America	16,711,400	11.50	31.94
Finland	10,948,100	7.53	39.48
Sweden	9,956,570	6.85	46.33
Germany	9,949,750	6.85	53.17
France	5,907,560	4.06	57.24
Indonesia	5,578,100	3.84	61.08
Austria	4,280,470	2.95	64.02
China	3,911,350	2.69	66.71
Russian Federation	3,756,810	2.58	69.30
Belgium	3,573,740	2.46	71.75
Brazil	3,218,430	2.21	73.97
Italy	2,741,710	1.89	75.86
Malaysia	2,722,230	1.87	77.73
Netherlands	2,652,810	1.83	79.55
United Kingdom	2,195,140	1.51	81.06
Japan	1,934,200	1.33	82.40
Chile	1,890,330	1.30	83.70
Spain	1,842,830	1.27	84.96
Norway	1,831,850	1.26	86.22
Korea, Republic of	1,624,250	1.12	87.34
Switzerland	1,515,780	1.04	88.38
New Zealand	1,468,530	1.01	89.39
Portugal	1,284,770	0.88	90.28
Poland	1,018,000	0.70	90.98

the second largest exporting region, representing around 30% of the total value declining over time. Asia is also a significant exporter, with around 13% of the value, while the regions of Africa, Oceania and South America are minor exporters.

The same picture also holds for imports (Table 7). Countries in Europe represent approximately 45% of the value of imports, followed by Asian countries (28%) and North and Central America (22%).

Canada is by far the largest single exporter of forest products, alone accounting for 20% of the total export value in 2000 (Table 8). USA follows second (11.5%), Finland (7.5%) and Sweden (6.9%) being the largest European exporters. The 25 countries listed in the table, all with exports of forest products in excess of 1 billion USD, represent more than 90% of the world's export value in forest products.

3.4. Trade in wood fuel

Data on trade flows in wood fuels are obtained from the European Forest Institute (EFI) [18]. This database is constructed from United Nations COMTRADE data and is elaborated and maintained by B. Michie and P. Wardle at the European Forest Institute.

Trade flows between different countries of a wide range of forestry-related products and over several years can be extracted from the database. When it comes to trade in wood fuels, the database contains a handful of products that are relevant. Data are focused on:

- charcoal;
- wood chips and wood particles;
- fuel wood;
- wood residues.

This database does not contain explicit data on trade in wood pellets (or briquettes).

Data on trade are presented in the different wood-based fuels by means of export/import matrices. In Tables 9–11 the major features of trade in charcoal, wood chips and particles, fuel wood, and wood residues are analysed. Among these, charcoal and fuel wood are likely to be used for energy purposes, while chips/particles and residues are potentially used for energy, but may also have other uses for example in the forest products industry (pulp mills and particle board industries). It is not clear from the statistics for which purpose these two latter product categories are traded.

The data are extracted from the EFI database one country at a time. Deriving complete global trade statistics on several commodities in this way is rather cumbersome; therefore, the following procedure was followed. Based on an expansion of the list of forest exports in Table 8, the 25 largest countries in terms of forest product exports were identified. It is assumed that these countries are also large exporters of wood-based fuels. For each of these countries, total export volumes of the above-mentioned fuel categories, distributed by importing countries, have been obtained from the database. These country data were then sorted by export and import volumes, respectively, to obtain the export/import matrices.

The matrices (Tables 9–12) should be read in the following way. The data columns represent values for a given exporting country (indicated by the '*x*'-prefix to the abbreviated country name). Also, the exporting countries (columns) are ordered according to the size of the total export volume. In Table 9, we find that Indonesia (*x*-indo) is the largest exporter of charcoal (358,364 tonnes) followed by Malaysia (240,843 tonnes). Due to space constraints these tables do not contain the full matrices, only the 15 largest exporters are presented individually. The remaining 19 countries (of a total of 34 also including all other importing countries) are aggregated in the '*x*-other'-column. The same procedure is for Tables 9–12

Each line in the table represents the single importing countries. These are also sorted by size, and Table 9 demonstrates that Japan is the largest importer of charcoal (325,655 ton) followed by the Republic of Korea and Germany. The individual cells in the table's show which amounts are imported by the country in the table line from the country in the table column. The tables thus show the trade flows between the different countries, and it is expected that the largest volumes of trade appear in the upper left corner of the table.

As seen in Table 9, more than half of the world trade in charcoal originates in the Asian countries of Indonesia, Malaysia and China, with Japan and Korea being the major importers. Germany is by far the largest European importer, followed by Norway and UK. Poland is the largest exporter of charcoal in Europe, followed by Spain and France.

Trade in wood chips and particles is summarised in Table 10. Again Japan is the largest importer, now by far, accounting for well over 60% of world trade. Four countries dominate exports: USA, Australia, Chile and China.

The fuel wood trade shows a different structure (Table 11). This trade takes place mainly within countries in Europe and North America. In North America, the trade is in both directions between Canada and USA. In Europe, France, UK, The Czech Republic, Russia and Latvia are the largest exporters while Belgium and Ireland are the largest importers.

A similar pattern is evident in the trade of wood residues (Table 12). Germany, France and Austria, together with Canada are the largest exporting countries. The bulk of Canadian exports go to USA, while exports from the European countries go to large importers such as Italy, Germany, Belgium, the Netherlands and France.

4. Discussion

Forest resources are identified as one of the major supplies of renewable energy as wood fibre in different forms. Today, round wood is used for domestic heating all over the world using traditional techniques. Sometimes it is purchased on the open market but it is more common for local forest land owners to cut their energy supply for the cold season and may be for cooking from their own small wood lots. Controlled firewood cutting also occurs on public lands by local users. This small-scale use of wood for energy has a high value for the user and constitutes a significant level of cuttings and energy but could be a problem when cutting is illegal.

The interest for wood resources of many kinds will increase when the Kyoto Agreement and instruments to fulfil a reduction of greenhouse gases are established.

Commercially, logging residues like tops and branches are already established for energy extraction in some Nordic countries and in North America. The forest products industry; i.e. sawmills, the panel industry and the pulp and paper industry are the main industrial users of timber and wood fibre. The industry produces wood and paper products but also produces by-products during the process. By-products trade and use are complex with rather complicated trade patterns. For example, in the production of sawn wood the mill produces significant amounts of sawdust and chips, which are used in the pulp- and board industry. Bark is mainly used for internal energy use at the mill, and sometimes by local municipalities. At worse it is deposited in landfills.

What is 'new' in this market balance is the increased demand for wood for energy outside the forest products industry. This creates competition between traditional users and the energy industry, mainly regarding small-diameter wood and by-products.

The waste sector has grown strong in recent years, in Europe mainly due to EU waste legislation. The result is that large amounts of fibre are being recycled for use in the paperboard industry and for energy use.

Table 9
Trade in charcoal, metric tonnes (2000 and 2001 average)

	x_{indo}	x_{mal}	x_{chn}	x_{pol}	x_{sing}	x_{spa}	x_{fra}	x_{rom}	x_{USA}	x_{ned}	x_{bel}	x_{bra}	x_{lat}	x_{ger}	x_{cze}	$x_{\text{all other}}$	Sum imp.
Japan	51,266	120,196	132,814	0	15,401	0	0	0	1303	0	0	97	0	295	0	4284	325,655
Korea, Rep.	82,047	94,014	60,389	0	1359	0	95	0	387	0	0	0	0	35	0	1800	240,125
Germany	3405	0	37	67,411	0	3754	16,417	22,699	536	2429	5494	1473	304	0	5297	5772	135,026
Norway	59,531	0	577	5603	0	826	11	0	51	108	0	3248	2125	29	528	796	73,432
Taiwan	44,587	3532	13,795	0	5949	0	0	0	56	0	0	0	0	0	0	3240	71,159
UK	26,727	1439	31	206	267	17,623	688	29	2991	165	59	8958	0	484	0	1394	61,058
Belgium	2680	16,744	4	1909	17,527	319	8419	18	2	402	0	431	385	230	1110	268	50,444
France	1038	0	92	1540	0	12,477	0	0	74	2411	6960	393	5198	1598	1671	629	34,078
Singapore	31,755	1726	0	0	0	0	0	0	103	10	0	0	0	0	0	158	33,751
Denmark	191	0	14	4086	0	10,296	9915	0	0	14	75	0	2222	1266	29	3989	32,094
Sweden	224	0	110	19,934	154	267	0	37	130	2	0	0	7612	1561	29	1734	31,791
Malaysia	29,201	0	0	0	156	0	0	0	34	0	0	0	0	143	0	1288	30,821
Hong Kong	2425	0	10,619	0	11,214	0	0	0	17	0	0	0	0	25	0	733	25,032
United States	2332	71	1049	91	0	0	34	0	0	2995	0	938	0	1124	0	9687	18,320
Netherlands	194	32	26	2701	0	3787	334	22	194	0	7528	0	150	1860	29	344	17,198
Italy	1821	83	39	18	0	1114	287	6888	54	14	27	3915	0	854	79	195	15,383
Canada	69	0	50	38	0	0	23	0	11,331	1925	0	0	0	8	0	1795	15,236
Switzerland	290	0	0	6649	0	571	1843	1388	16	251	3	0	0	213	3308	621	15,151
Kuwait	1608	24	0	0	3554	0	0	53	345	3695	0	0	0	969	0	2122	12,369
UAE	5378	1042	5	0	487	0	0	0	2637	911	0	0	0	0	0	527	10,985
Portugal	0	0	0	0	0	6868	112	0	0	138	0	1502	0	19	0	3	8640
China	3898	181	0	0	96	0	0	0	37	0	25	0	0	0	0	3059	7295
SaudiArabia	1813	268	195	0	1308	0	505	0	908	254	0	0	0	29	43	1615	6936
Poland	221	0	0	0	0	0	0	0	344	145	0	0	48	352	131	5084	6324
Mexico	19	0	6	16	0	24	3	0	4483	0	0	0	0	69	0	1619	6237
Hungary	4	0	74	0	0	8	9	5357	0	4	46	0	0	0	40	0	5540
Lebanon	99	0	0	0	0	83	0	21	34	4655	0	38	0	2	0	283	5213
Bahrain	685	375	100	0	2973	0	0	0	5	416	0	0	0	0	0	0	4554
Qatar	246	26	50	0	2952	0	0	0	52	1	0	0	0	9	0	834	4169
Ireland	27	0	64	0	0	20	0	0	2896	18	73	0	0	0	0	650	3746
Austria	0	0	7	63	0	373	0	2203	0	378	23	0	0	268	0	290	3602
Spain	68	0	6	0	0	0	2222	29	50	83	48	278	0	42	0	600	3423
Luxembourg	0	0	0	0	0	51	1173	0	0	42	1406	0	32	417	0	57	3178
Finland	150	0	37	148	0	74	99	0	0	18	0	0	861	14	0	1560	2958
All other importers	4369	1093	3861	453	1724	707	291	1559	6099	1796	210	431	710	865	88	10,118	34,371
Sum exports	358,364	240,843	224,045	110,861	65,117	59,238	42,475	40,299	35,162	23,273	21,975	21,700	19,645	12,776	12,380	67,139	1,355,288

Table 10
Trade in wood chips and particles, cubic metres (2000 and 2001 average)

	x_{USA}	x_{aus}	x_{chi}	x_{chn}	x_{ger}	x_{bra}	x_{can}	x_{thai}	x_{lat}	x_{rus}	x_{fra}	x_{aut}	x_{nzl}	x_{mal}	x_{swe}	$x_{all\ other}$	Sum imp.
Japan	4,331,294	4,164,341	4,038,143	1,416,872	63	964,562	719,089	810,966	0	186,682	28	16	373,468	318,908	0	71,160	17,395,590
Canada	1,739,644	105	0	172	239	0	0	10	0	0	351	0	0	255	0	1173	1,741,948
Taiwan	39,690	76,414	0	732,538	168	0	0	74,778	0	0	0	0	0	25,310	0	91,094	1,039,990
Sweden	35	0	49	0	38,227	128,298	233	0	589,723	2903	0	0	0	254	0	257,261	1,016,982
Korea, Rep.	246,082	163,011	7837	408,066	241	0	12	4995	0	0	52	0	11,993	0	0	3836	846,123
Italy	237,712	166	0	0	32,745	0	0	0	0	0	143,157	326,528	0	51	0	37,216	777,573
Austria	0	0	0	0	606,016	0	13	0	0	0	7	0	0	0	0	29,896	635,932
Finland	2928	0	0	0	9905	0	0	12	105,227	483,711	0	7	0	0	12,780	526	615,093
USA	0	10	70,035	4170	23	0	321,940	325	0	40	3839	31	0	225	0	212	400,846
Norway	0	0	0	0	18,456	0	0	0	29,083	14,972	0	0	0	0	280,768	14,350	357,628
Belgium	234	0	0	0	146,285	0	0	0	2749	0	129,744	3378	0	0	68	17,376	299,832
France	6586	0	0	12	132,511	0	297	0	251	0	0	510	0	0	7230	108,610	256,006
Germany	1520	190	0	12	0	6	0	0	69	6	41,289	6694	0	48	2550	132,547	184,929
Netherlands	212	0	0	262	164,237	0	0	0	2289	0	2496	0	0	0	296	1707	171,497
Indonesia	839	133,285	0	22,632	13	0	0	46	0	0	0	0	157	608	0	0	157,578
Spain	8 055	0	0	120	464	50,491	955	0	0	0	62,736	0	0	0	218	6054	129,092
Switzerland	254	0	0	0	50,085	0	0	0	0	0	68,914	7993	0	0	0	227	127,472
Luxembourg	0	0	0	0	40 252	0	0	0	0	0	20,225	5	0	0	0	31,663	92,144
Slovenia	0	0	0	0	90	0	0	0	0	0	0	69,312	0	0	0	49	69,451
Portugal	68	0	0	0	33,008	0	0	0	0	0	23,905	0	0	0	0	296	57,276
China	15,592	17	25,338	0	321	1298	4057	16	0	0	432	0	0	49	0	3207	50,325
Denmark	0	0	0	0	3349	0	0	0	60	0	786	0	0	0	18,831	20,313	43,338
Colombia	102	0	26,536	0	3	0	0	0	0	0	0	0	0	0	0	15	26,655
UK	5490	0	0	8	1475	0	271	559	8418	0	70	0	0	0	358	9049	25,696
Ireland	221	0	0	0	46	0	0	0	0	0	480	1713	0	0	145	21,354	23,958
Mexico	22,022	0	0	0	0	0	0	0	0	0	0	17	0	0	0	82	22,121
Hong Kong	1040	110	0	6276	73	0	0	12,894	0	0	0	0	0	0	0	1156	21,548
Czech Rep.	140	0	0	0	17,435	0	0	0	0	0	0	3360	0	0	0	2	20,936
Lebanon	149	0	16,238	0	313	0	0	0	0	0	82	0	0	0	0	49	16,830
Slovakia	0	0	0	0	73	0	0	0	5210	0	0	0	0	0	0	10,524	15,806
Singapore	241	251	0	63	25	0	9	9	0	0	0	0	0	54	0	10,222	10,871
Australia	7430	0	0	0	227	0	17	0	0	0	1257	0	13	0	0	852	9796
Saudi Arabia	312	0	0	0	131	0	978	185	0	161	0	235	0	310	4092	2206	8609
Chile	7299	2	0	0	0	0	0	0	0	0	331	0	0	0	0	0	7632
All other imp.	19,095	1776	467	8753	5064	434	2700	37	56	2351	5159	891	83	5222	329	13,141	65,554
Sum exp.	6,694,281	4,539,675	4,184,642	2,599,952	1,301,555	1,145,088	1,050,568	904,830	743,133	690,825	505,333	420,686	385,713	351,292	327,662	897,419	26,742,650

Table 11
Trade in fuelwood, cubic metres (2000 and 2001 average)

	x_{fra}	x_{USA}	x_{UK}	x_{cze}	x_{rus}	x_{can}	x_{lat}	x_{spa}	x_{ger}	x_{indo}	x_{swe}	x_{swl}	x_{pol}	x_{bel}	x_{ned}	$x_{\text{all other}}$	Sum imp.
Belgium	197,779	185	0	0	0	0	0	0	7435	68	0	0	58	0	2915	218	208,657
USA	76	0	7999	0	0	163,975	0	0	74	9750	143	0	0	0	0	1645	183,661
Ireland	33	111	173,581	0	0	519	0	27	1849	0	928	0	0	171	0	402	177,618
Austria	0	0	0	142,383	0	0	28	0	5061	0	0	520	331	0	0	824	149,145
Finland	0	0	0	0	143,262	0	0	0	71	31	0	0	0	0	116	332	143,811
Italy	42,080	1503	141	24,993	0	358	0	1442	3384	15	249	41,136	111	112	1940	23,413	140,874
Sweden	0	1384	662	0	30,555	2084	90,607	0	39	0	0	0	1049	0	858	7559	134,795
France	0	830	21,815	142	0	0	0	80,923	305	833	5956	785	715	9615	1679	3541	127,135
Denmark	0	219	0	167	53	0	43,478	0	26,048	0	4718	0	17,423	0	203	627	92,934
Canada	1163	89,876	0	0	0	0	0	0	0	54	68	0	0	0	184	131	91,476
Germany	2570	1322	0	37,991	67	13	75	0	0	131	4261	535	7577	732	11,669	1895	68,834
Bahamas	0	62,746	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62,746
Norway	97	0	0	0	584	301	8934	0	11	0	24,933	0	901	0	1741	3220	40,719
Japan	0	4291	0	0	10,620	93	0	0	0	8711	0	0	0	0	0	12,897	36,610
Luxembourg	13,573	0	0	0	0	0	0	0	224	0	0	0	0	14,990	0	0	28,786
Switzerland	23,859	0	0	46	0	0	0	0	449	0	18	0	0	62	0	261	24,695
Taiwan	968	7313	0	0	0	0	0	0	201	2140	0	272	0	0	0	12,858	23,751
Korea, Rep.	0	7722	0	0	642	0	0	0	0	3386	0	0	0	0	0	7202	18,951
China	0	1389	0	0	3357	713	0	0	77	9345	0	0	0	0	0	3112	17,993
UK	11	6304	0	15	125	1203	852	0	0	1605	1421	0	1350	26	962	649	14,520
Indonesia	0	368	0	0	0	0	0	0	0	0	0	0	0	0	0	13,351	13,719
Greece	0	0	0	0	0	244	0	3453	3055	0	0	0	0	0	1472	5265	13,489
Spain	840	681	0	31	13	0	0	0	0	19	0	0	0	0	11	11,398	12,992
Netherlands	497	1360	13	0	0	44	0	0	677	474	0	0	2885	6498	0	315	12,762
Turkey	1018	1131	0	0	3411	0	0	0	0	0	0	0	0	0	0	6699	12,258
CostaRica	0	10,524	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10,524
Mexico	0	5487	0	0	0	0	0	0	0	698	0	0	0	0	0	0	6184
Singapore	0	98	0	0	0	0	0	0	0	2240	0	0	0	0	0	2801	5138
Saudi Arabia	1655	290	40	128	0	0	0	280	23	1929	0	0	0	0	58	173	4574
Portugal	1009	0	0	0	0	0	0	2143	0	0	0	13	0	0	1109	13	4286
Hong Kong	0	58	63	0	0	0	0	0	35	3829	0	0	0	0	0	269	4253
Malaysia	0	1134	0	0	0	0	0	0	0	141	0	0	0	0	0	2825	4099
Andorra	166	0	0	0	0	0	0	2507	0	0	0	0	0	0	0	0	2673
India	31	249	0	0	0	0	0	0	217	1454	0	0	0	0	0	336	2286
All other importers	2140	10,961	1834	151	4092	501	255	242	413	344	852	0	13	0	260	7951	30,007
Sum exports	289,562	217,528	206,145	206,044	196,778	170,046	144,227	91,016	49,643	47,192	43,543	43,260	32,410	32,205	25,176	132,174	1,926,946

Table 12
Trade in wood residues, cubic metres (2000 and 2001 average)

	x_{ger}	x_{fra}	x_{aut}	x_{can}	x_{bel}	x_{swi}	x_{cze}	x_{lat}	x_{USA}	x_{ned}	x_{indo}	x_{swe}	x_{pol}	x_{spa}	x_{fin}	x_{other}	Sum imp.
Italy	139,348	220,666	368,869	239	4560	351,163	148	150	5622	458	13	0	823	3100	0	9366	1,104,522
Germany	0	149,058	232,194	434	158,247	33,993	231,307	389	3022	50,655	64	4708	49,459	690	631	2859	917,705
Belgium	332,213	453,395	48	1680	0	33	0	6278	1770	44,300	939	26	86	1306	0	1466	843,537
Netherl.	308,747	39,437	6377	5119	167,441	461	34	856	319	0	7	1047	14,438	985	5132	1365	551,763
USA	3387	4210	0	479,157	2046	0	0	2078	0	2062	282	0	0	1680	40	8194	503,134
France	227,835	0	490	167	126,028	12,254	2311	0	347	11,028	245	12	33	16,546	0	8932	406,225
Sweden	18,247	349	0	76,973	283	0	169	174,577	85	934	0	0	1972	0	35,145	25,908	334,641
Denmark	21,009	1783	0	76	105	0	9135	69,317	0	3339	0	49,779	27,840	629	23,838	8977	215,824
Austria	88,483	1821	0	0	86	19,353	51,027	0	11	53	0	71	2159	9	540	3443	167,053
Switzerland	71,839	55,057	10,890	239	28	0	222	0	312	1162	9	0	161	0	0	927	140,843
Luxemb.	7848	22,737	204	0	95,382	0	0	0	33	1 036	0	0	0	0	0	0	127,239
Korea, Rep.	30	40	0	100	0	0	0	0	9403	0	89,975	154	0	31	0	16,955	116,686
Japan	7755	289	45	13,584	0	0	0	0	5257	24,632	15,056	0	0	0	0	44,512	111,128
Spain	695	37,101	2297	690	91	0	17	0	5459	461	37	258	0	0	0	45,654	92,757
UK	11,680	20,164	0	79	2347	0	15	2790	1158	8456	78	3991	316	33,443	326	952	85,791
Norway	3555	1200	784	0	72	0	0	7441	240	8876	0	54,957	1991	0	1116	2338	82,568
Finland	5100	64	0	0	5	0	0	0	0	8	0	731	467	0	0	63,596	69,970
Canada	987	594	0	0	16	0	0	0	47,121	512	50	7	0	159	0	3099	52,543
Argentina	0	11,220	0	118	0	0	0	0	20,877	0	0	0	0	0	0	337	32,551
Australia	118	437	12	10	0	0	0	0	26 891	111	1533	22	0	0	0	2169	31,302
Taiwan	194	706	0	1026	0	0	0	0	2861	89	16,443	0	0	0	91	8554	29,964
Chile	0	2471	0	45	0	0	0	0	22,195	0	0	0	0	0	0	64	24,775
Portugal	11,566	2404	0	333	392	0	0	0	0	310	0	12	0	9075	0	47	24,137
Mexico	0	177	0	170	0	0	0	0	19,379	0	0	0	0	0	0	558	20,283
Singapore	250	0	0	1542	0	0	0	0	109	2735	10,782	391	0	0	0	2973	18,781
HongKong	399	1422	0	2139	90	21	0	0	8721	1697	436	0	0	0	0	2484	17,408
Bahamas	0	0	0	0	0	0	0	0	14,685	0	0	0	0	0	0	0	14,685
UAE	2368	10	0	0	0	0	0	0	0	8387	65	467	0	0	0	691	11,987
Slovenia	270	80	7830	0	0	0	120	0	696	227	0	0	0	172	0	167	9560
Saudi Arab.	3644	1826	53	0	0	0	0	0	230	10	487	0	0	17	0	1744	8009
Nigeria	8008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8008
Czech Rep.	964	0	6483	0	0	0	0	0	0	86	0	0	178	0	0	277	7987
Brazil	70	366	0	31	0	0	0	0	6415	153	8	0	0	0	0	173	7214
Greece	288	91	0	773	790	0	0	0	1639	135	0	0	535	207	0	1937	6392
Oth. imp.	12,733	8536	2411	5483	755	1100	2308	166	8341	4532	3666	3872	722	2763	370	27,910	85,665
Sum exp.	1,289,621	1,037,705	638,984	590,202	558,759	418,377	296,812	264,040	213,191	176,438	140,169	120,502	101,177	70,807	67,226	298,623	6,282,628

Wood-based energy production could be expected to increase for heat and steam production. However for electricity production in CHP, electricity prices must rise significantly or new technologies be developed to reach profitability. It leads to the conclusion of a short-term increase for heat production and a longer perspective for CHP to be economically advantageous.

The trend is for an increased use of wood in different markets—first of low cost and lower qualities, and later of more expensive, processed products. This is true for both forest products industry and for the energy industry. New quality regulations or certification could also influence this trend. The competition starts with low-value fibre, possibly without any other commercial use and when demands rises, other wood or better timber qualities will be affected. The energy industries, where some are very powerful and financially strong, look for new fuels from the forest sector, from the waste sector, from the agriculture sector and elsewhere. For them biofuels is one renewable energy source competing with another, i.e. solar panels, wind energy, small-scale hydro or other techniques.

The international trade patterns show different pictures in this study due to what kind of wood product that is analysed. Export of round wood dominates from Asia while more upgraded assortments like sawn wood show a pattern with Europe as the dominant region.

Africa and Asia dominate charcoal production. Quantities are significant and are here estimated to be 1800 million cubic metres.

Export in forest products origins mainly from Europe, America and Asia and importing regions are often in the same geographic area.

Trade in wood fuel is rather new and not as established as for round wood or sawn wood. Large importers of charcoal are countries like Japan, Korea, Germany and Norway, which reflect large demand and strong or rather strong economies. Large exporters are Indonesia, Malaysia and China.

Dominant importers of wood chips and particles are by far Japan but surprisingly also countries rich in forest resources per capita like Canada and Sweden. Large exporting countries are the United States of America, Austria and China.

Fuelwood is imported mainly to European countries like Belgium, Ireland and Austria but also the United States of America. Exporters are France and the United States of America.

These patterns reflect the demand for resources but also the market situation were domestic wood fuel may be more expensive than imported wood fuel. This is a situation similar to most other traded products and nothing unique for bioenergy.

When the demand for renewable energy increases these trade patterns may be changed. Countries with large forest resources will increase their export and countries dependent on fossil fuels in today's energy system will increase their import. There is a risk that less-developed countries will export their renewable energy in favour of fossil fuels while high industrialised and developed countries will benefit. As long as forest resources are larger than the demand this could be a good solution in the short run but in the longer run other patterns with more local use may occur.

5. Conclusions

Wood fuels, traditionally used in local domestic heating, are now also traded internationally for industrial use, thanks mainly to new energy promotion policies but also commercial driving forces are also involved.

In the past decade the industrial use of wood for energy production has increased significantly in different regions and individual countries i.e. the Kyoto Agreement.

Increased prices for fossil fuels make it more profitable to use alternatives, among them wood for energy. In the past years environmental concern has also become a strong driver behind the increased interest for wood energy.

Bioenergy/wood-fuel promotion policy in certain countries and within the European Union indicate an increased competition between traditional users of wood fibre, round wood and manufacturing by-products and users of wood fuel.

A new actor has appeared on the scene for wood raw material—the modern bio-fuel energy production industry. What this will lead to in the future is an open question, the development of the future energy and forestry policies as well as market prices and the availability of woody biomass for energy purposes will impact on the answer.

International trade in wood fuel is strong in Europe, Southeast Asia and North America. However, trade are in these regions is limited to certain countries.

The short-term trend is that countries and regions with a stronger position in economy and development will increase their use and import of wood fuel while less-developed countries will continue their development based on fossil fuels. This might be changed in the long term.

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